植物分类学报 28 (1): 10—26 (1990)
Acta Phytotaxonomica Sinica

金缕梅科(广义)的叶表皮特征*

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CHARACTERS OF LEAF EPIDERMIS IN HAMAMELIDACEAE (S. L.)

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Summary Observed under LM in the present work were epidermal cells and stomatal apparatuses of mature leaves in 37 species (50 samples) belonging to 19 genera and 6 subfamilies (Hamamelidaceae), of which 35 species (19 genera, 6 subfamilies) were also used for observing under SEM cuticular membrane and wax sculpture, shape of stomata and stucture of stomatal apparatuses of the lower epidermis.

(1) It is found that in the family cells of both upper and lower epidermis are tetragonal, pentagonal and hexagonal or irregular; anticlinal walls are straight, arched, sinuolate and sinuate; stomatal apparatuses, which occur only on the lower surface, may be cyclocytic, stephanocytic, paracytic and anomocytic. All these characters of the leaf epidermis are of systematic significance in the family (Fig. 1).

(2) Types of stomatal apparatuses are correlated to a certain extent with the pattern of anticlinal walls of epidermal cells and other external morphological characters. In the majority of cases, the groups, whose stomatal apparatuses are cyclocytic (Exbucklandioideae and Rhodoleioideae) and stephanocytic (*Mytilaria* Lec. and *Tetrathyrium* Benth.), all have straight or arched anticlinal walls of lower and upper epidermal cells (except for *Exbucklandia tonkinensis* with sinuate anticlinal walls of both upper and lower epidermal cells, and *E. longipetala* with sinuate anticlinal walls of upper epidermal cells) (Plate 1:12, 13; 2:4), are all evergreen trees or shrubs, and all have palmate veins and simple hairs (but Rhodoleioideae is pinnate-veined or obscurely trinervious and has tufted hairs), indefinite floral parts and numerous ovules, while the groups, whose stomatal apparatuses are paracytic (Disanthoideae, *Chunia* H. T. Chang, Liquidambaroideae and Hamamelidoideae, which also has anomocytic type in small portion of species) (Table 2), have sinuolate or sinuate anticlinal walls of upper and lower epidermal cells (except for *Chunia, Tetrathyrium, Corylopsis brevistyla* and *C. willmotiae*, which have straight and arched anticlinal walls), are mostly deciduous trees and shrubs, and have pinnate veins and tufted hairs in most species, usually tetra-, or pentamerous flowers (except for Liquidambaroideae, which has indefinite floral parts) and usually single ovule (but

* 国家自然科学基金资助课题。
1988.04.15 收稿

Disanthoideae and Liquidambaroideae have numerous ovules).

(3) The subfamily Liquidambaroideae possesses polyporate pollen grains (Chang 1958, 1979), a circular vascular system in the midrib, at the centre of which is situated a secretory channel (Huang 1982, 1986) and leaf teeth of the unique Altingioid tooth type (Li 1988) etc. Based on these characters some authors tend to support the separation of the subfamily as a family, Altingiaceae. The subfamily, however, shows strong differentiation of characters. For example, in the subfamily, there are both evergreen and deciduous trees, palmate and pinnate leaf veins, capitate, short-spicate and racemose inflorescences and half-interior and inferior ovaries. Furthermore, some characters in the subfamily, which are considered important for the separation, are crisscross with those in the other members of the Hamamelidaceae. Their stomatal apparatuses are similar to those in most groups of Hamamelidaceae (paracytic), and *Sycopsis sinensis* also possesses polyporate pollen grains. The subfamily shares with the remaining members of Hamamelidaceae many important characters, such as the presence of stipule, two styles, 2-locular ovary, axial placenta, capsule. From the data available the separation of the subfamily does not seem to be supported by adequate evidence, and it may well be a link of the Hamamelidaceae with the related families.

(4) Considering the fact that the subfamily Disanthoideae and most members of the subfamily Hamamelidoideae are of paracytic stomatal apparatuses and pentamerous flowers, the present authors tend to agree with Huang's (1986) view that the subfamily Disanthoideae is more closely related than the other subfamilies to Hamamelidoideae.

(5) Leaf epidermis of the family under study shows great diversity under SEM, even within a genus in some cases, but it is generally stable at subfamily or genus level, and therefore SEM characters of the leaf epidermis is of certain taxonomic significance. For example, Exbucklandioideae possesses ovate stomata. The cuticular membrane is annular around stomata (Plate 3:3—6); most stomata are covered with lump-like cuticular membranes in Rhodoleioideae (Plate 3:7,8,11,12); in *Mytilaria* the cuticular membrane appears lump-like, with a minute-scaly waxy ornamentation (Plate 3:9); the cuticular membrane is striate, with large scales on it in *Chunia* (Plate 3:10), and it is vermicular in *Sycopsis* (Plate 5: 9—11). Some differences were also found among species in a genus, for instance, among the three species in *Corylopsis* (Plate 4: 12—14 and Table 2).

Key words Hamamelidaceae; Leaf epidermis; Stomatal apparatuses

摘要 本文次氯酸钠及铬酸-硝酸离析法，在光学显微镜下，观察了 19 属 37 种(分属六个亚科)共 50 个样品的成熟叶表皮细胞及气孔器的特征，发现金缕梅科植物叶上下表皮细胞形状(表面观)为多边形和不规则形，垂周壁式样有平直、弓形和有波纹；气孔器仅在下表皮存在，其类型有环列型、冠列型、平列型和无规则型(图 1)几种。在扫描电镜下观察了 19 属 35 种(分属六个亚科)的叶下表皮的角质膜和蜡质纹饰、气孔的形状、气孔外拱盖及拱盖内缘的特征。这些特征在亚科或属级水平上较为稳定，但有的也表现出种间差异，有一定的分类学价值。

关键词 金缕梅科；叶表皮；气孔器

金缕梅科 (Hamamelidaceae) 全世界共 29 属，约 140 种，分布于热带及亚热带。亚洲东部有 21 属约 100 种，为该科的现代分布中心。我国有 17 属约 75 种，多集中于南部各省区。本科多数原始属分布于我国，对于进一步探讨金缕梅科植物的起源和进化提供了有价值的研究材料。关于金缕梅科的概念，学者们曾有一些不同的意见，主要分歧是枫

香树亚科（Liquidambaroideae）是否应独立成科——阿丁枫科（Altingiaceae)。为了研究金缕梅类植物的系统发育和进化，对金缕梅科植物作全面比较研究是重要的研究内容之一，我们将陆续进行报道。

近20年来，叶表皮性状，特别是气孔器类型的研究受到越来越多的重视，叶结构特征的多样性过去多用于种间或属间分类和系统关系的探讨，但对科以上分类单元系统关系的研究也有一定的价值，例如：Dahlgren（1985）将气孔器的不同类型也用于对单子叶植物系统问题的研究。金缕梅科植物叶表皮细胞及气孔器类型的研究，只有Metcalfe和Chalk（1950）作过零星报道，为此作者进行了较全面的比较研究。

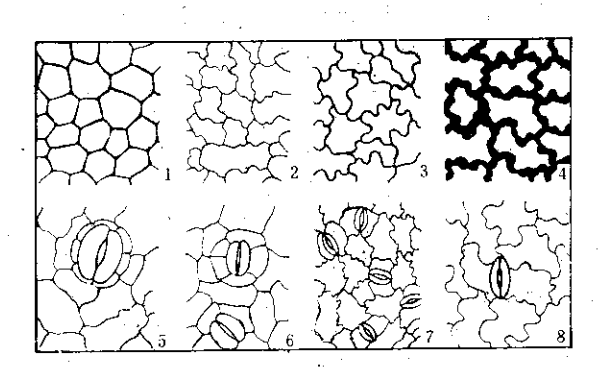


图1 金缕梅科植物成熟叶表皮细胞形状及气孔器(表面观)类型

1. 红花荷，示多边形，垂周壁平直、弓形。2. 山白树，示不规则形，垂周壁浅波纹。3. 细柄蕈树，示不规则形，垂周壁深波纹。4. 枫香树，示不规则形，垂周壁节状加厚。5. 大果马蹄荷，示环列型×。6. 壳菜果，示冠列型×。7. 檵木，示平列型。8. 日本金缕梅，示无规则型(张泰利绘)。

Fig. 1. Shape of epidermal cells and type of stomatal apparatuses of mature leaves (surface view) in Hamamelidaceae

1. *Rhodoleia championii*, showing polygonal cells, straight or arched anticlinal walls. 2. *Sinowilsonia henry*, showing irregular cells, sinuolate anticlinal walls. 3. *Altingia gracilipes*, showing irregular cells, sinuate anticlinal walls. 4. *Liquidamber formosana*, showing ireegular cells, nodular thickening of anticlinal walls. 5. *Exbucklandia tonkinensis*, showing cyclocytic type of stomatal apparatuses. 6. *Mytilaria laosensis*, showing stephanocytic of type of stomatal apparatuses. 7. *Loropetalum chinense*, showing paracytic type of stomatal apparatuses. 8. *Hamamelis japonicus* var. *flavo-purpurascens* showing anomocytic type of stomatal apparatuses. (drawn by Zhang Tai-li)

1,2,7.×100; 3,4,5,6,8.×160.

材料与方法

本文研究的实验材料，全部采自本所植物标本馆腊叶标本（附录1）。

取成熟叶中部一小块，用水煮沸软化约10分钟（时间长短，因材料而定)后，浸泡在4—5%的次氯酸钠或铬酸-硝酸离析液中，在室温或30—40℃温箱中放1—2天，待叶肉组织与上、下表皮开始分离时，把离析后的材料用水洗净，移入盛有蒸馏水的容器中，撕下表皮，去掉叶肉组织，在载玻片上用1%的番红酒精(50%)溶液染色约3—5分钟(时间长短视材料而定)，按常规法制片。在光学显微镜下观察拍照或投影描图。用于扫描电镜下观察的材料，直接将一小块成熟完好的干叶片贴在胶纸上，镀膜在扫描电镜（SEM）Hitachi

S-800 下观察、拍摄照片。在同样倍数下(物镜 40 × 目镜 10)测量 10 个视野或 10 个细胞,取其平均值。气孔指数计算按如下公式进行：

$$I = \frac{S}{E + S} \times 100$$

本文所用术语参考 Dilcher (1974); Wilkinson (1979) 和 Baranova (1987)。

分类群排列按照张宏达 (1979) 采用的分类系统。仅分布于国外的属参照 Harms (1930)。

观 察 结 果

(一) 叶表皮在光学显微镜下的特征(表 1)

1. 叶片上表皮：上表皮无气孔器，表皮细胞(表面观)的垂周壁多数种类具不同程度的加厚，仅山白树 *Sinowilsonia henryi* Hemsl. 不加厚或加厚不明显。根据细胞形状和垂周壁的式样,可分为两种类型：

(1) 表皮细胞 4—6 边形，大小不等，垂周壁平直 (straight) 或弓形 (arched)，如 *Exbucklandia populnea*, *E. aricupis*, *Rhodoleia championii*, *R. stenopetala*, *R. parvipetala*, *R. teysmannii*, *Mytilaria laosensis*, *Chunia bucklandioides*, *Tetrathyrium subcordatum*, *Corylopsis brevistyla*, *C. willmottiae*, *Fortunearia sinensis*(图版 1：1—10；图 2：1,5)。

(2) 表皮细胞形状不规则,近相等或稍不等,垂周壁浅波纹或深波纹，如 *Disanthus cercidifolius*, *Exbucklandia longipetala*, *E. tonkinensis*, *Liquidambar formosana*, *Semiliquidambar cathayensis* var. *parvifolia*, *Altingia yunnanensis*, *A. chinensis*, *A. gracilipes*, *Loropetalum chinense*, *Hamamelis mollis*, *H. virginiana*, *H. japonicus* var. *flavo-purpurascens*, *Corylopsis multiflora*, *Eustigma oblongifolium*, *Fothergilla parvifolia*, *F. monticalla*, *Parrottiopsis jaquemontiona*, *Sinowilsonia henryi*, *Distylium chinense*, *D. myricoides*, *D. buxifolium*, *D. racemosum*, *Sycopsis tutcheri*, *S. dunnii*, *S. sinensis* (图版 1：11—32;图 2：2—4)。但 *Liquidambar formosana* 垂周壁成节状加厚(图版 1：14)。

2. 叶片下表皮：下表皮上的气孔器 (stomatal apparatus (Wilkinson 1979)) 或称气孔复合体 (stomatal complex (Dilcher 1974; Baranova 1987)) 全部散生，保卫细胞外壁有不同形状或不同程度的加厚 (本文称气孔外拱盖 outer stomatal ledge or rim (Wilkinson, 1979))；两极成棒状或"T"形加厚，有时有四个小而近圆形的薄壁区。根据副卫细胞 (subsidiary cells) 的形状、数目和排列,气孔器可分为以下四种类型：

(1) **环列型** (cyclocytic type)。 5—6 个副卫细胞围绕着保卫细胞，副卫细胞小而狭窄,大小不等,保卫细胞稍下陷。由于副卫细胞有时被发育较好的角质膜覆盖，因此由它们所组成的围绕保卫细胞的环界限不十分明显;表皮细胞多边形,垂周壁平直、弓形,如 *Exbucklandia populnea*, *E. aricupis*, *E. longipetala*, *Rhodoleia chamipionii*, *R. parvipetala*, *R. seysmanuri* (图版 2：1—3,5,6；图 2：6,7)；垂周壁浅波纹,如 *Exbucklandia tonkinensis* (图版 2：4)。

Table 1. The characters of leaf epidermis and the types of stomatal

character / taxon	Upper epidermis (adaxial)		
	shape of cells	pattern of anticlinal walls	shape of cells
I. Subfam. Disanthoideae *Disanthus cercidifolius*	irregular	sinuolate	irregular
II. Subfam. Exbucklandioideae *Exbucklandia populnea*	polygonal	straight arched	polygonal
E. aricupis	ditto	ditto	ditto
E. longipetala	irregular	sinuolate	ditto
E. tonkinensis	ditto	ditto	irregular
III. Subfam. Rhodoleioideae *Rhodoleia championii*	polygonal	straight, arched	polygonal
R. stenopetala	ditto	ditto	ditto
R. parvipetala	ditto	ditto	ditto
R. teysmannii	ditto	ditto	ditto
IV. Subfam. Mytilarioideae *Mytilaria laosensis*	ditto	ditto	ditto
Chunia bucklandioides	ditto	ditto	ditto
V. Subfam. Liquidambaroideae *Liquidambar formosana*	irregular	sinuate	irregular
Semiliquidambar cathayensis var. *parvifolia*	ditto	ditto	ditto
Altingia yunnanensis	ditto	sinuolate	ditto
A. chinense	ditto	ditto	ditto
A. gracilipes	ditto	ditto	ditto
VI. Subfam. Hamamelidoideae 1. Trib. Hamamelideae *Tetrathyrium subcordatum*	polygonal	straight, arched	polygonal
Loropetalum chinense	irregular	sinuolate	irregular

apparatuses in Hamamelidaceae under LM (Surface view)

Lower epidermis (abaxial)				Plate or Figure
pattern of anticlinal walls	size of stomata (μ)	stomatal index	type of stomatal apparatus	
sinuolate	20.3×17.7	13.7	paracytic	Pl. 1:11 2:9
straight arched	36.0×26.9	13.8	cyclocytic	Pl. 1:1 2:1
ditto	33.3×28.3	21.7	ditto	Pl. 1:2 2:2
ditto	43.8×32.8	13.1	ditto	Pl. 1:12 2:3
sinuolate	42.3×33.6	14.8	ditto	Pl. 1:13; 2:4
straight, arched	26.6×21.3	18.7	ditto	Pl. 1:3 Fig. 2:6
ditto	23.6×20.6	23.5	ditto	Pl. 1:4 2:5
ditto	23.6×21.9	19.9	ditto	Fig. 2:1,7
ditto	34.4×23.4	21.2	ditto	Pl. 1:5 2:6
ditto	21.7×14.1	14.2	stephanocytic	Pl. 1:6 2:7
ditto	24.1×21.3	23.1	paracytic	Pl. 1:7
sinuolate	19.2×18.0	28.4	ditto	Pl. 1:14 2:10
ditto	21.4×18.3	27.9	ditto	Pl. 1:15 2:11
ditto	22.0×19.1	34.6	ditto	Pl. 1:16 2:11
ditto	22.7×17.3	30.5	ditto	Pl. 1:17 Fig. 2:9
sinuate	24.5×20.6	32.8	ditto	Pl. 1:18 2:13
straight, arched	28.9×23.3	19.4	stephanocytic	Pl. 1:8 2:8
sinuate	24.5×20.6	28.7	paracytic	Pl. 1:19 2:14

taxon \ character	Upper epidermis (adaxial)		
	shape of cells	pattern of anticlinal walls	shape of cells
Hamamelis mollis	ditto	ditto	ditto
H. virginiana	ditto	ditto	ditto
H. japonicus var. *flavo-purpurascens*	ditto	sinuate	ditto
2. Trib. Corylopsideae *Corylopsis brevistyla*	polygonal	straight, arched	ditto
C. willmottiae	ditto	ditto	ditto
C. multiflora	irregular	sinuolate	ditto
Fortunearia sinensis	polygonal	straight arched	ditto
3. Trib. Eustigmateae *Eustigma oblongifolium*	irregular	sinuolate	ditto
4. Trib. Fothergilleae *Fothergilla parvifolia*	ditto	ditto	ditto
F. monticalla	ditto	ditto	ditto
Parrotiopsis jacquemontiona	ditto	ditto	ditto
5. Trib. Distylteae *Sinowilsonia henryi*	ditto	ditto	ditto
Distylium myricoides	ditto	sinuate	ditto
D. racemosum	ditto	ditto	ditto
D. chinense	ditto	sinuolate	ditto
D. buxifolium	ditto	sinuate	ditto
Sycopsis tutcheri	ditto	sinuolate	ditto
S. dunnii	ditto	ditto	ditto
S. sinensis	ditto	ditto	ditto

(Cont.)

Lower epidermis (abaxial)				Plate or Figure
pattern of anticlinal walls	size of stomata (μ)	stomatal index	type of stomatal apparatus	
sinuolate	23.0×18.8	58.2	ditto	Pl. 1:20 2:15
sinuate	28.6×16.4	18.6	ditto	Fig. 2:2 2:14
ditto	33.1×20.8	35.5	anomocytic paracytic	Pl. 1:21 2:22
sinuolate	19.0×13.8	24.4	ditto	Pl. 1:9 Fig. 3:3
ditto	21.6×14.4	34.4	ditto	Pl. 1:10 Fig. 3:4
ditto	14.3×15.2	35.2	ditto	Pl. 1:23 Fig. 3:5
ditto	26.9×14.1	22.3	paracytic	Fig. 2:5,10
sinuate	23.4×13.1	21.9	ditto	Pl. 1:22 2:16
sinuolate	24.7×18.4	34.4	ditto	Fig. 2:3,11
ditto	32.2×17.5	41.3	anomocytic paracytic	Fig. 2:4, 12
ditto	23.4×14.2	29.8	ditto	Pl. 1:24 Fig. 2:13
sinuate	28.1×20.1	16.7	ditto	Pl. 1:25 Fig. 3:6
ditto	26.4×15.6	18.6	paracytic	Pl. 1:27 2:17
ditto	22.9×16.7	18.1	ditto	Pl. 1:29; 2:18
sinuolate	24.4×17.7	29.5	ditto	Pl. 1:26;Fig. 2:14
sinuate	22.8×16.3	29.8	ditto	Pl. 1:28; Fig.2:15
sinuolate	23.3×18.6	22.3	ditto	Pl. 1:30; 2:19 Fig. 3:2
sinuate	24.4×21.1	20.7	ditto	Pl. 1:31; 2:20
ditto	27.2×19.7	20.6	ditto	Pl. 1:32; 2:21

Table 2 The characters of the lower epidermis of

taxon		Stomatal shape	Ornamentation of outer stomatal ledge (or rim)
I. Subfam. Disanthoideae	*Disanthus cercidifolius*	suborbicular	finely granular
	D. cercidifolius var. *longipes*	elliptic	indistinct
II. Subfam. Exbucklandioideae	*Exbucklandia aricupis*	ovate	granular
	E. populnea	ditto	smooth
	E. longipetala	ditto	ditto
	E. tonkinensis	ditto	ditto
III. Subfam. Rhodoleioideae	*Rhodoleia parvipetala*	indistinct	indistinct
	R. championii	ditto	ditto
	R. forrestii	ditto	ditto
	R. teysmannii	ovate	filiform-striate
IV. Subfam. Mytilarioideae	*Mytilaria laosensis*	elliptic	smooth
	Chunia bucklandioides	suborbicular	granular
V. Subfam. Liquidambaroideae	*Liquidambar formosana*	ditto	smooth
	L. acalycina	ditto	nearly smooth or spinulate
	Semiliquidambar cathayensis	ditto	sparsely fine-granular
	Altingia chinensis	ditto	ditto
	A. gracilipes	ditto	ditto
	A. yunnanensis	ditto	ditto

leaves in Hamamelidaceae under SEM

Inner margin of outer stomatal ledge (or rim)	Cuticular membrane	Wax ornamentation	Plate
smooth	insular	sparsely and inely granularf	3:1
undulate	ditto	densely and finely granular	3:2
sinuolate	insular, but annular around stomata	finely granular, fine-striate and reticulate	3:3
smooth	striate, but annular around stomata	ditto	3:4
ditto	undulate-striate, annular around stomata	spinulate	3:5
nearly smooth	ditto	finely granular	3:6
indistinct	insular	ditto	3:7
ditto	ditto	ditto	3:8
ditto	ditto	ditto	3:11,12
nearly smooth	ditto	filiform-striate finely-striate and reticulate	3:13
spiny-processed	ditto	fine-scaly	3:9
nearly smooth	thick-striate, crass-scaly	ditto	3:10
sinuolate	thick-striate	sparsely fine-granular	3:14
ditto	ditto	spinulate	4:1,2
ditto	cyclic	fine-striate and reticulate, finely granular	4:3
ditto	ditto	finely granular	4:4
nearly smooth	ditto	thick-striate, fine-striate and reticular, finely granular	4:5
ditto	ditto	thick-striate and reticular, crass and thick-scaly, finely granular	4:6

taxon \ character		Stomatal shape	Ornamentation of outer stomatal ledge (or rim)
VI. Subfam. Hamamelidoideae	1. Trib. Hamamelideae *Tetrathyrium subcordatum*	elliptic	smooth
	Loropetalum chinense	ovate	ditto
	Hamamelis mollis	ditto	ditto
	H. virginiana	oblong	ditto
	2. Trib. Corylopsideae *Corylopsis brevistyla*	ovate	densely and finely granular
	C. willmottiae	ditto	smooth
	C. multiflora	indistinct	indistinct
	Fortunearia sinensis	elliptic	smooth
	3. Trib. Fothergilleae *Fothergilla parvifolia*	oblong	ditto
	F. monticalla	ditto	ditto
	Parratiusis jacquementiona	ditto	ditto
	4. Trib. Eustigmateae *Eustigma oblongifolium*	ditto	ditto
	5. Trib. Distylteae *Sinowilsonia henryi*	ovate	ditto
	Distylium racemosum	suborbicular	nearly smooth
	D. chinense	elliptic	ditto
	Sycopsis tutcheri	ovate	ditto
	S. sinensis	ditto	ditto

(Cont.)

Inner margin of outer stomatal ledge (or rim)	Cuticular membrane	Wax ornamentation	Plate
sinuolate	undulate-striate, annular around stomata	nearly smooth	4:8,9
finely spiny-processed	undulate-striate and reticular	spinulate	4:7
sinuolate	radiate-striate	densely and finely granular	4:10
ditto	rugose-undulate	finely granular	4:11
ditto	insular	fine-scaly, granular	4:12
nearly smooth	striate	smooth	4:13
indistinct	ditto	spinulate-scaly	4:14
smooth	rugose-striate	smooth	5:3,4
ditto	insular	sparsely fine-granular and thick-scaly	5:1,2
ditto	striate	pillar-striate	5:5
ditto	rugose-striate	sparsely fine-granular, fine-striate and reticular, scaly	5:14
ditto	insular	fine-granular	5:6
sinuolate	fine-striate and winged	smooth	5:8
ditto	cyclic	spinulate, fine-striate	5:7
nearly smooth	ditto	fine-granular, fine-striate	5:12,13
finely spiny-processed	vermiform	filiform-striate and reticular	5:9
ditto	ditto	fine-scaly	5:10,11

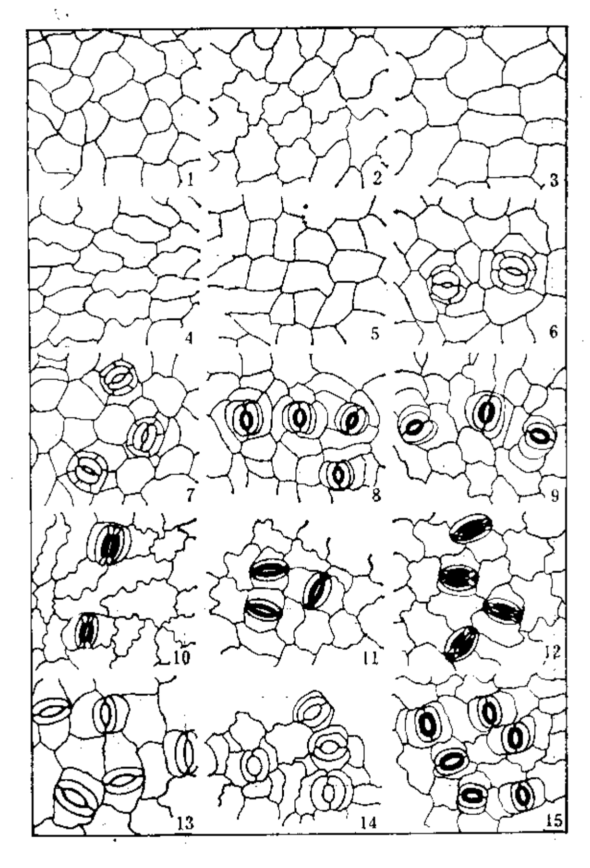


图 2 金缕梅科植物成熟叶表皮细胞形状及气孔器的类型(表面观): 1—5. 叶上表皮细胞形状及垂周壁式样。6—15. 叶下表皮细胞形状及气孔器类型(解释见图 1)(张泰利绘)。

Fig. 2 Shape of epidermal cells and type of stomatal apparatuses of mature leaves in Hamamelidaceae (surface view): (1—5) Shape of upper epidermal cells and pattern of anticlinal walls of mature leaves. (6—15)Shape of lower epidermal cells and type of stomatal apparatuses of mature leaves. (see Fig.1. for explanation) (drawn by Zhang Tai-li).

1. *Rhodoleia parvipetala*; 2. *Hamamelis virginiana*; 3. *Fothergilla parvifolia*; 4. *F. monticalla*; 5. *Fortunearia sinensis*; 6. *Rhodoleia chamipionii*; 7. *R. parvipetala*; 8. *Chunia bucklandioides*; 9. *Altingia chinensis*; 10. *Fortunearia sinensis*; 11. *Fothergilla parvifolia*; 12. *F. monticalla*; 13. *Parrottiopsis jacquemontiona*; 14. *Distylium chinense*; 15. *D. buxifolium*. 1—2, 5—10,12,14,15.×160; 4. ×100; 13. ×250.

(2) **冠列型** (stephanocytic type) (Baranova 1987)。保卫细胞由 4 或 5 个副卫细胞所围绕，副卫细胞较宽，保卫细胞两极的副卫细胞比其余的宽，成冠状；表皮细胞为多边形，垂周壁平直、弓形，如 *Mytilaria laosensis*, *Tetrathyrium subcordatum* (图版 2: 7,8)。

(3) **平列型**(paracytic type)。两个副卫细胞完全包围保卫细胞，狭窄或翅状延长，大小不等，与保卫细胞的长轴平行；表皮细胞形状不规则，垂周壁有波纹 (仅 *Chunia bucklandioides* 为多边形，垂周壁平直、弓形)。如 *Disanthus cercidifolius*, *Liquidambar formosana*, *Semiliquidambar cathayensis* var. *parvifolia*, *Altingia yunnanensis*, *A. chinensis*, *A. gracilipes*, *Loropetalum chinense*, *Hamamelis mollis*, *H. virginiana*, *Fortunearia sinensis*, *Eustigma oblongifolium*, *Fothergia parvifolia*, *Parrottiopsis jacquemontiona*, *Distylium chinense*, *D. mycicoides*, *D. buxifolium*, *D. racemosum*, *Sycopsis tutcheri*, *S. dunnii*, *S. sinensis* (图版 2: 9—21; 图 2: 8—15; 3: 1—2)。

(4) 无规则型 (anomocytic type)。4—7 个普通表皮细胞围绕着保卫细胞。这一类型，在金缕梅科中是罕见的，多出现在蜡瓣花属 *Corylopsis* Sieb. et Zucc. 中，往往与平列型同时出现在同一种植物中如 *Corylopsis brevistyla*, *C. willmottiae*, *C. multiflora*, *Forthergilla monticalla*, *Hamamelis japonicus* var. *flavo-purpurascens*, *Sinowilsonia henryi* (图版 2: 22;图 2: 13;3: 3—6)。

(二) 叶下表皮外表面在扫描电镜 (SEM) 下的特征：由于材料较多，限于文章篇幅，简要描述和比较见表 2 和图版 3—5。

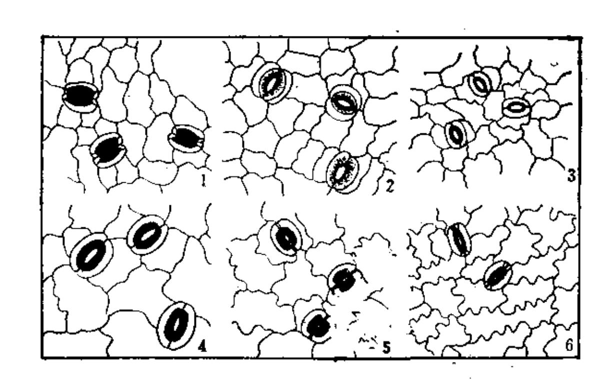


图3　金缕梅科植物成熟叶下表皮细胞形状及气孔器类型(表面观)。(张泰利绘)。

Fig. 3 Shape of epidermal cells and type of stomatal apparatuses of lower epidermis of mature leaves in Hamamelidaceae (surface view).

1. *Hamamelis virginiana*; 2. *Sycopsis tutcheri*; 3. *Corylopsis brevistyla*; 4. *C. willmottiae*; 5. *C. multiflora*; 6. *Sinowilsonia henryi* (drawn by Zhang Tai-li).

1—3,6 ×160; 4,5. ×250

讨论和结论

1. 金缕梅科植物叶片上、下表皮细胞(表面观)垂周壁式样为平直、弓形和有波纹，气孔器散生于下表皮(图 1：1—4)

2. 金缕梅科植物叶片气孔器的类型，除以前报道的平列型(Metcalfe and Chalk 1950)外，还有环列型，冠列型和无规则型(图 1：5—8)。

3. 金缕梅科植物叶表皮气孔器的类型与它们表皮细胞垂周壁式样及其它形态特征之间有一定相关关系。在大多数情况下，凡气孔器为环列型(马蹄荷亚科 Exbucklandioideae 和红花荷亚科 Rhodoleioideae)、冠列型(壳菜果属 *Mytilaria* Lec. 四药门花属 *Tetrathyrium* Benth.)的类群，其叶片上下表皮细胞的垂周壁式样都是平直和弓形的(除 *Exbucklandia tonkinensis* 垂周壁浅波纹，*E. longipetala* 上表皮细胞垂周壁浅波纹外)(图版 1：12,13;2：4)，都为常绿乔木或灌木，多为掌状脉，单毛(红花荷亚科为羽状脉或不明显三出脉，簇生毛)，花基数不定，胚珠多数。凡气孔器为平列型的类群(双花木亚科 Disanthoideae，山铜材属 *Chunia* H. T. Chang 枫香树亚科 Liquidambaroideae，金缕梅亚科 Hamamelideae 中有少数种类兼有无规则型(见表 1)，其叶片上下表皮细胞的垂周壁式样都是有波纹的(除山铜材属、四药门花属、*Corylopsis brevistyla* 和 *C. willmottiae* 平直和弓形外)，以落叶乔灌木为主，多数种类为羽状脉、簇生毛，花基数通常 4—5(枫香树亚科为不定数)。胚珠通常 1 枚(双花木亚科和枫香树亚科具多数胚珠)。

4. 枫香树亚科(Liquidambaroideae)具多孔花粉(张金谈，1958，1979)，中脉维管束系呈环形、环中央具分泌道(黄桂玲和李正理，1982；黄桂玲，1986)以及叶片的齿型为独特的阿丁枫型(李浩敏，1988)等特征，有的作者支持将枫香树亚科独立为科——阿丁枫科(Altingiaceae)。但枫香树亚科性状分化较复杂、不少性状都有交叉，如既有常绿乔木也有落叶乔木；叶脉有掌状也有羽状；花序有头状、短穗状和总状；子房有半下位和下位；气孔器的类型又与金缕梅科中大多数类群相似(为平列型)，多孔花粉又与水丝梨属 *Sycopsis* Oliv. 的水丝梨 *S. sinensis* 相类似。在形态构造上，如具托叶、花柱2、子房 2 室、中轴胎座、果为蒴果等许多重要性状都属金缕梅科的特征。因此，从目前掌握的资料来看，还不能支持枫香树亚科独立成科的观点，它很可能是金缕梅科联系其它亲缘科的环节。

5. 从叶表皮气孔器的类型分析，双花木亚科与金缕梅亚科中的大多数类群的气孔器都是平列型，花基数 5，我们支持黄桂玲(1986)的观点，它比其它亚科更接近于金缕梅亚

科。

6. 从表 2 及图版 3，4，5 中可以看出，在扫描电镜下，叶片下表皮外面的特征如气孔形状，气孔外拱盖及外拱盖内缘的特征、副卫细胞及表皮细胞外表面的角质膜或蜡质纹饰等，都具有多种形态，差异极大。但在亚科或属级水平上也有较为稳定的性状，如马蹄荷亚科的气孔为卵圆形，外拱盖表面多平滑，稀具小颗粒，拱盖内缘平滑，稀浅波状，角质膜在气孔周围呈圆形包着气孔(图版 3：3—6)；红花荷亚科的多数气孔被块状角质膜所覆盖(图版3：7,8,11,12)；枫香树亚科气孔为近圆形，外拱盖多具小颗粒，角质膜呈环状或粗条纹(图版 3：14;4：1—6)。壳菜果属气孔椭圆形，外拱盖平滑，拱盖内缘具小刺状突起，角质膜呈块状，具小鳞片状蜡质纹饰(图版 3：9)；山铜材属气孔近圆形，外拱盖具颗粒状纹饰，拱盖内缘近平滑，角质膜呈条状其上具大型鳞片(图版 3：10)；水丝梨属，角质膜为蠕虫状(图版 5：9—11)。在同属植物中也表现出种间差异，如蜡瓣花属的三个种(图版4：12—14 和表 2)，因此植物叶片在扫描电镜下角质膜和蜡质纹饰所表现出来的特征，也有一定的分类学价值。但是，值得注意的是，叶表面的某些性状易受环境条件的影响，如气孔的闭合程度，颗粒纹饰的疏密及在叶表面的分布等。所以在选择鉴别性状时要注意性状的稳定性。

Appendix: the origin of materials

[1] *Disanthus cercidifolius* Maxim. Japan. Middle Honshu, small tree 5 m., N. Fukuoka 7551(SEM); Tokyo in cultivation, K. Ueda 430.

[2] *D. cercidifolius* var. *longipes* H. T. Chang Hunan: Dao Xian, K. Y. Pan and al *87005.

[3] *Exbucklandia populea* (R. Br.) R. W. Brown Yunnan: Kiukiang valley chihgnanlaka, 1800 m. T. T. Yü 18045; Guizhou: Xingren County, Y. T. Chang and Z. S. Chang *7973.

[4] *E. aricupis* Hullf. Indonesia, H. F. Sun s626(SEM).

[5] *E. longipetala* H. T. Chang Guizhou: Rongjiang County, Taiyang Mountain, Exped. to southern Guizhou 3337(SEM).

[6] *E. tonkinensis* (Lec.) Steenis Guangdong: Liannan County, 820m. P. C. Tan 59161 (SEM).

[7] *Rhodoleia championii* Hook. f. Guangdong: Longmen County, 680 m. C. F. Wei 121956 (SEM).

[8] *R. parvipetala* Tong Yunnan: Malipo County, 1300—1400 m. K. M. Feng 13930(SEM).

[9] *R. forrestii* Chun ex Exell Yunnan: Exped. Qingzang 19337(SEM).

[10] *R. stenopetala* H. T. Chang Hainan: Wuzhi Mountain, 1300 m. N. J. Chen 44057.

[11] *R. teysmannii* Miq. Indonesia, H. F. Sun 5623(SEM).

[12] *Mytilaria laosensis* Lec. Guangxi: Shangsi County, 402 m. collector unknown 2113(SEM).

[13] *Chunia bucklandioides* H. T. Chang Hainan: Ledong County, Jaingfeng Mountain, collector unknown, no number (SEM).

[14] *Liquidambar formosana* Hance Guizhou: Luodian County, 550 m. Exped. to southern Guizhou 799(SEM); Guangdong: Pingyuan County, X. G. Li 201914(SEM).

[15] *L. acalycina* H. T. Chang Hunan: Xinning County, Ziyun Mountain, L. H. Liu 15228(SEM).

[16] *Semiliquidambar cathayensis* H. T. Chang Guangdong: X. P. Gao *53448.

[17] *S. cathayensis* var. *parvifolia* (Chun) H. T. Chang Guangxi: S. Q. Chen 17334.

[18] *Altingia yunnanensis* Rehd. et Wils. Yunnan: Pingbian County, 1600 m. H. T. Tsai 61466(SEM).

[19] *A. chinensis* (Champ.) Oliv. Guangxi: Rongshui County, S. Q. Chen 15723(SEM).

[20] *A. gracilipes* Hemsl. Guangdong: Jiaoling County. 500 m. L. Deng 4685(SEM); Fujian: Nanping County, collector unknown 129(SEM).

[21] *Tetrathyrium stbcordatum* Benth. Hongkong: W.Y. Chun 4869(SEM).

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* The asterisk indicates that the material was examined under scanning electron microscope only.

All the materials were taken from PE.

[22] *Loropetalum chinense* (R. Br.) Oliv. Sichuan: Fengjie County, 900 m. T. Y. Chang 25501(SEM).

[23] *Hamamelis mollis* Oliv. Anhui: Huangshan Mountain, 1670 m. H. X. Chow 790(SEM).

[24] *H. vitginiana* L. North America, Kentuck County, R. Cranfill 715(SEM).

[25] *H. japonicus* var. *flavo-purpurascens* Rehd. Japan, K. Clausen, S. Davis, C. Warren and M. Wolcott 79—125.

[26] *Corylopsis brevistyla* H. T. Chang Yunnan: Mengzi County, H. C. Wang 3741(SEM); Dali County, H. C. Wang 4584.

[27] *C. willmottiae* Rehd. Sichuan: Tianquan County, S. Y. Jiang 733786, T. H. Tu 4607(SEM), G. L. Qu 2351, Mt. Emei, S. B. Peng 6259(SEM).

[28] *C. multiflora* Hance Guizhou: Fanjing Mountain, 700 m. A. N. Steward, C. Y. Chiao and H. C. Cheo 722(SEM); Guangxi: Rongshui County, 600 m. Q. H. Lü 26.

[29] *Fortunearia sinensis* Rhed. et Wils. Jiangsu: Nanjing, M. Chen 444(SEM).

[30] *Fothergilla parvidolia* south-eastern U. S. A., T. G. Harbison 3738(SEM).

[31] *F. monticalla* Ashe The United States, collector unknown 4163.

[32] *Parrottiopsis jacquemontiona* (Decne) Rehd. Kashmir, T. N. Lion L5736(SEM).

[33] *Eustigma oblongifolium* Gardn. Guangxi: Rongshui County, 1100 m. S. Q. Chen 14375(1SEM).

[34] *Sinowilsonia henryi* Hemsl. Shaanxi: Foping County, P. C. Kuo 1533 (SEM).

[35] *Distrylium chinense* (Fr.) Diels Sichuan: Wushan County, T. P. Wang 10783(SEM).

[36] *D. racemosum* Sieb. et Zucc. Zhejiang: Hangzhou City, collector unknown 0830(SEM).

[37] *D. myricoides* Hemsl. Fujian: Shaxian County, T. S. Wang 367.

[38] *D. buxifolium* (Hance) Merr. Fujian: L. K. Ling 936.

[39] *Sycopsis dunnii* Hemsl. Hunan: Yizhang County, X. X. Liu 28885; D. L. Liu 0087.

[40] *S. sinensis* Oliv. Hubei: Badong County, H. C. Chow 855(SEM).

[41] *S. tutcheri* Hemsl. Hainan: Lingshui County, Wuzhi Mountain, Z. Haung 36555(SEM).

Note: "SEM" in parentheses indicates that the material was examined under both light microscope and scanning electron microscope.

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图版说明 Explanation of plates

图版 1: 金缕梅科植物在光学显微镜下叶上表皮细胞形状及周壁式样(表面观): 1—10. 示多边形;垂周壁平直或弓形。11—32. 示不规则形;垂周壁有波纹。

Plate 1: LM photographs of shape of epidermal cells and pattern of anticlinal walls of upper of leaves (surface view): 1—10. Polygonal cells; straight or arched anticlinal walls. 11—32. Irregular cells; sinuate anticlinal walls.

1. *Exbucklandia populnea*; 2. *E. aricupis*; 3. *Rhodoleia championii*; 4. *R. stenopetala*; 5. *R. teysmannii*; 6. *Mytilaria laosensis*; 7. *Chunia bucklandioides*; 8. *Tetrathyrium subcordatum*; 9. *Corylopsis brevistyla*; 10. *C. willmottiae*; 11. *Disanthus cercidifolius*; 12. *Exbucklandia longipetala*; 13. *E. tonkinensis*; 14. *Liquidamber formosana*; 15. *Semiliquidambar cathayensis* var. *parvifolia*; 16. *Altingia yunnanensis*; 17. *A. chinensis*; 18. *A. gracilipes*; 19. *Loropetalum chinense*; 20. *Hamamelis mollis*; 21. *H. japonicus* var. *flavo-purpu rascens*; 22. *Eustigma oblongifolium*; 23. *Corylopsis multiflora*; 24. *Parrottiopsis jacquemontiona*; 25. *Sinowilsonia henryi*; 26. *Distylium chinense*; 27. *D. myricoides*; 28. *D. buxifolium*; 29. *D.racemosum*; 30. *Sycopsis tutcheri*; 31. *S. dunnii*; 32. *S. sinensis*.

1—9,13,16, 17,20—22, 24—26, 29.×200; 10—12,14,15,18,19, 23,27,28,32. ×320; 31×160.

图版 2: 金缕梅科植在光学显微镜下叶下表皮细胞形状、垂周壁式样及气孔器的类型(表面观)。

Plate 2: LM photographs of shape of lower epidermal cells, patern of anticlinal walls and type of stomatal apparatuses of mature leaves (surface view): 1—6. Cyclocytic type of stomatal apparatuses; 7—8. Stephanocytic type of stomatal apparatuses; 9—22. Paracytic type of stomatal apparatuses.

1. *Exbucklandia populnea*; 2. *E. aricupis*; 3. *E. longipetala*; 4. *E. tonkinensis*; 5. *Rhodoleia stenopetala*; 6. *R. teysmannii*; 7. *Mytilaria laosensis*; 8. *Tetrathyrium subcordatum*; 9. *Disanthus cercidifolius*; 10. *Liquidambar formosana*; 11. *Semiliquidambar cathayensis* var. *parvifolia*; 12. *Altingia yunnanensis*; 13. *A. gracilipes*; 14. *Loropetalum chinense*; 15. *Hamamelis mollis*; 16. *Eustigma oblongifolium*; 17. *Distylium myricoides*; 18. *D. racemosum*; 19. *Sycopsis tutcheri*; 20. *S. dunnii*; 21. *S. sinensis*; 22. *Hamamelis japonicus* var. *flavo-purpurascens*.

1,2,14,16.×200; 3—13,15,19—22. ×320; 17,18. ×250.

图版 3 金缕梅科植物叶下表皮在扫描电镜下的特征

Plate 3: Characters of lower epidermis of mature leaves in Hamamelidaceae under SEM.

1. *Disanthus cercidifolius* ×1500; 2. *D. cercidifolius* var. *longipes* ×3000; 3. *Exbucklandia aricupis* ×1200; 4. *E. populnea* ×1500; 5. *E. longipetala* ×420; 6. *E. tonkinensis*×420; 7. *Rhodoleia parvipetala* ×420; 8. *R. championii* 900; 9. *Mytilaria laosensis* ×1200; 10. *Chunia bucklandioides* ×1200; 11—12. *Rhodoleia forrestii* ×600, 240; 13. *R. teysmannii* ×1200; 14. *Liquidambar formosana* × 1200.

图版 4: 金缕梅科植物叶下表皮在扫描电镜下的特征

Plate 4: Characters of lower epidermis of mature leaves in Hamamelidaceae under SEM

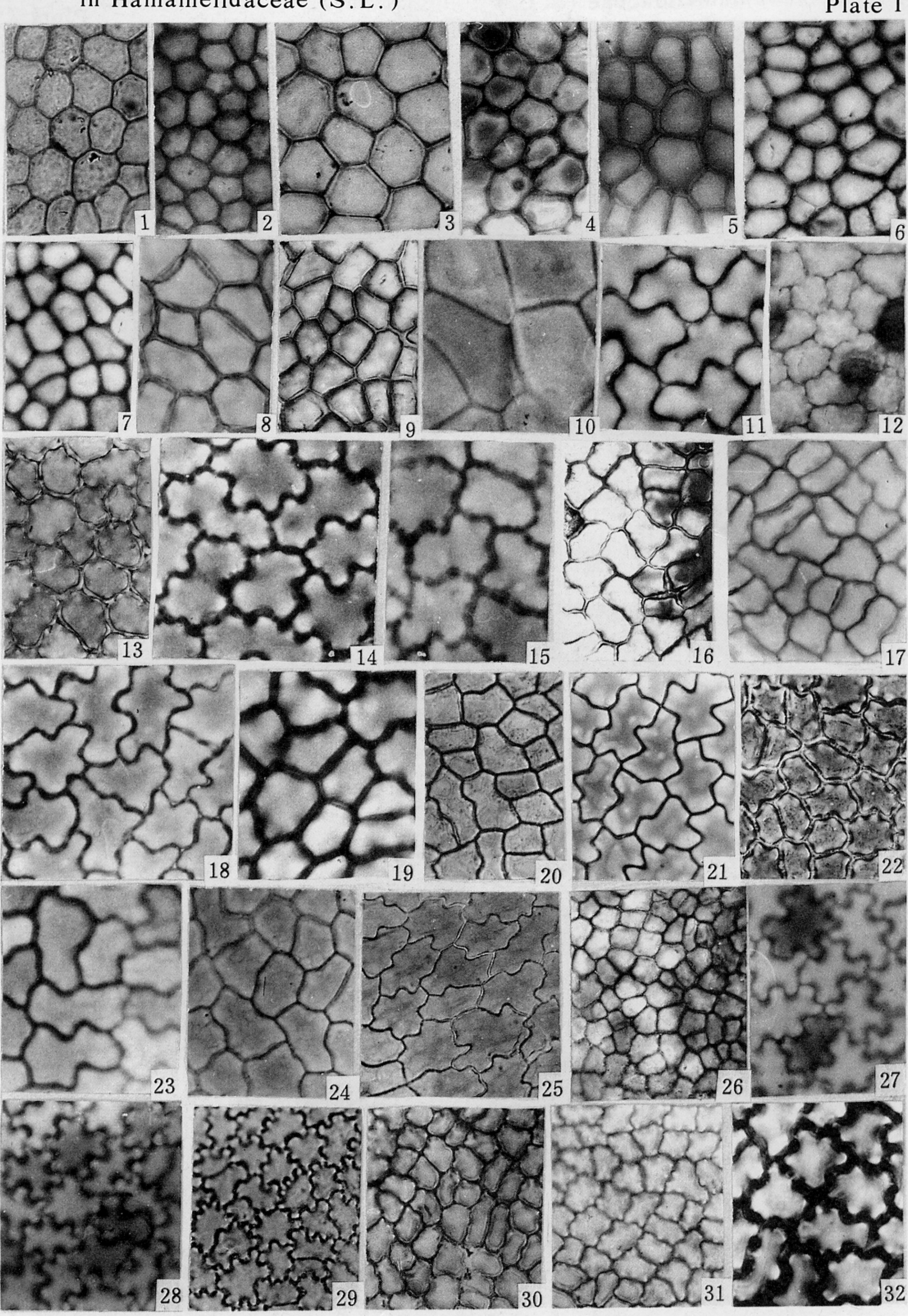
1—2. *Liquidambar acalycina* ×1200,300; 3. *Semiliquidambar cathayensis*; 4. *Altingia chinensis*; 5. *A. gracilipes*; 6. *A. yunnanensis*; 7. *Loropetalum chinense*; 8—9. *Tetrathyrium subcordatum* ×300, 1800; 10. *Hamamelis mollis*; 11. *H. virginiana*; 12. *Corylopsis brevistyla* ×1500; 13. *C. willmottiae*; 14. *C. multiflora*.

3—7, 10,11,13,14. ×1200

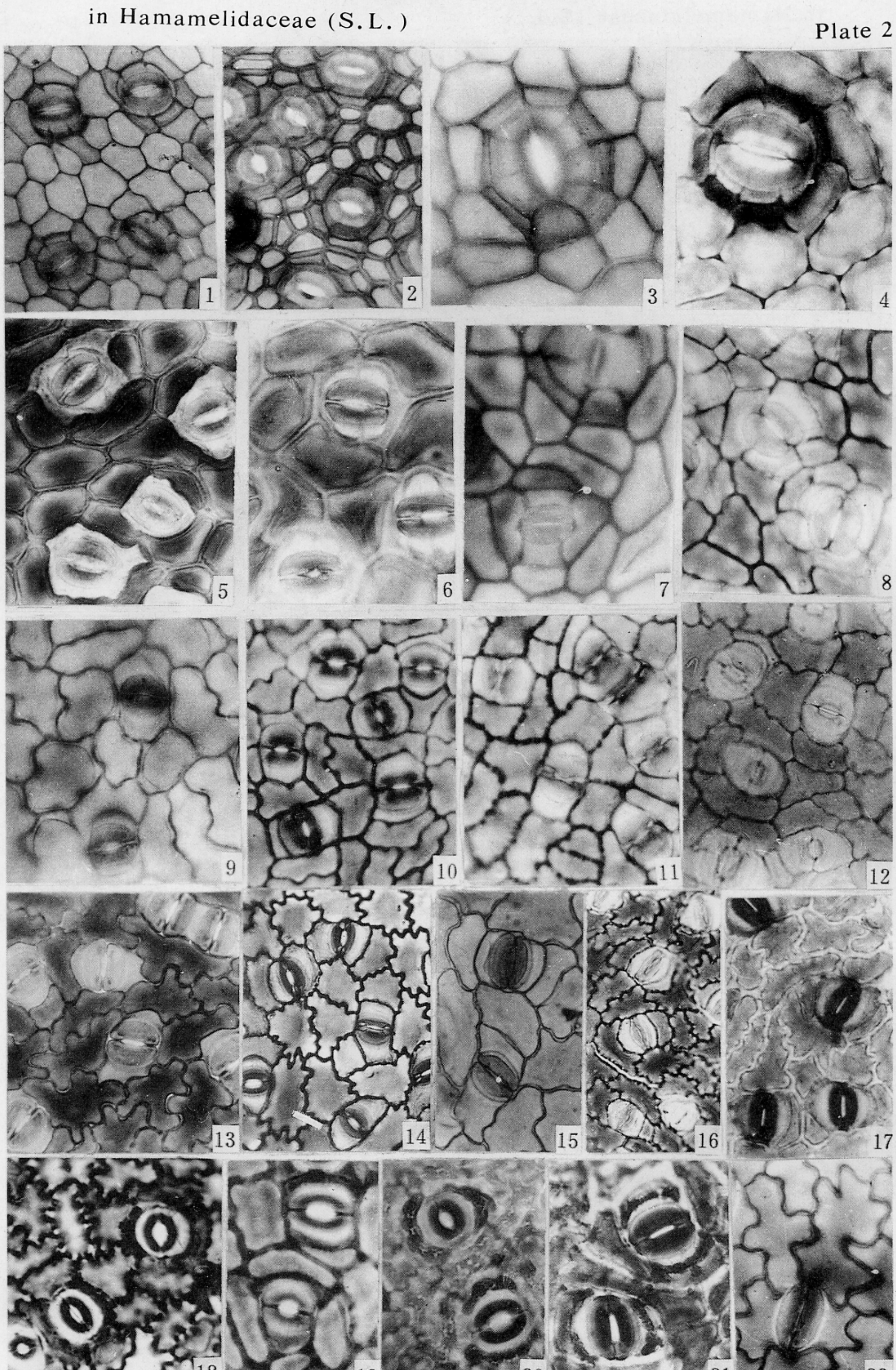
图版 5: 金缕梅科植物叶下表皮在扫描电镜下的特征

Plate 5: Characters of lower epidermis of mature leaves in Hamamelidaceae under SEM

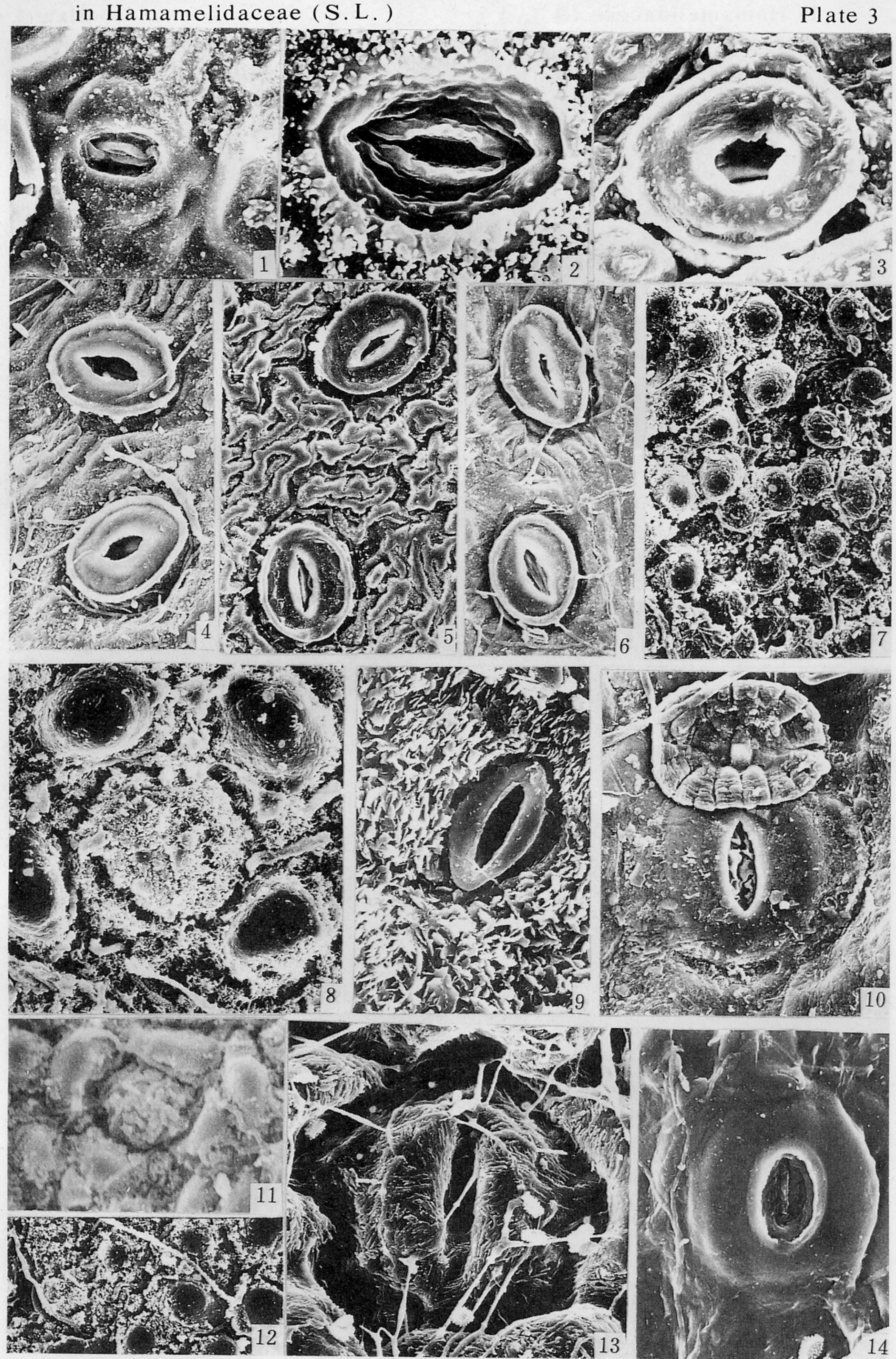
1—2. *Fothergilla parvifolia* ×420, 1200; 3—4. *Fortunearia sinensis* ×600,1500; 5. *Fothergilla monticalla* ×420; 6. *Eustigma oblongifolium* ×800; 7. *Distylium racemosum* ×1200; 8. *Sinowilsonia henryi* ×1200; 9. *Sycopsis tutcheri* ×1200; 10—11. *S. sinensis* ×420, 1200; 12—13. *Distylium chinensis* ×420,1200; 14. *Parrattiusis jacquementiona* ×420.

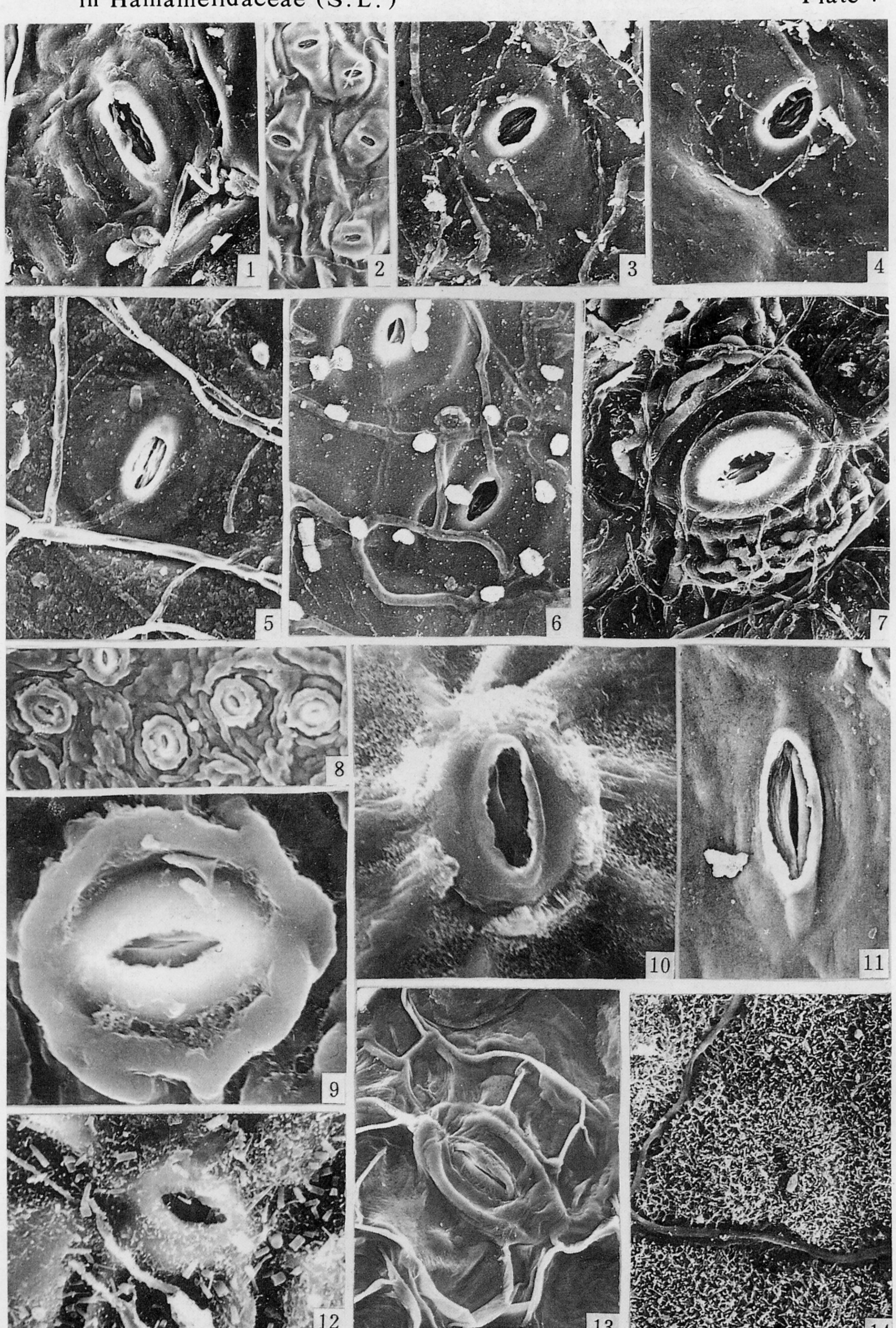


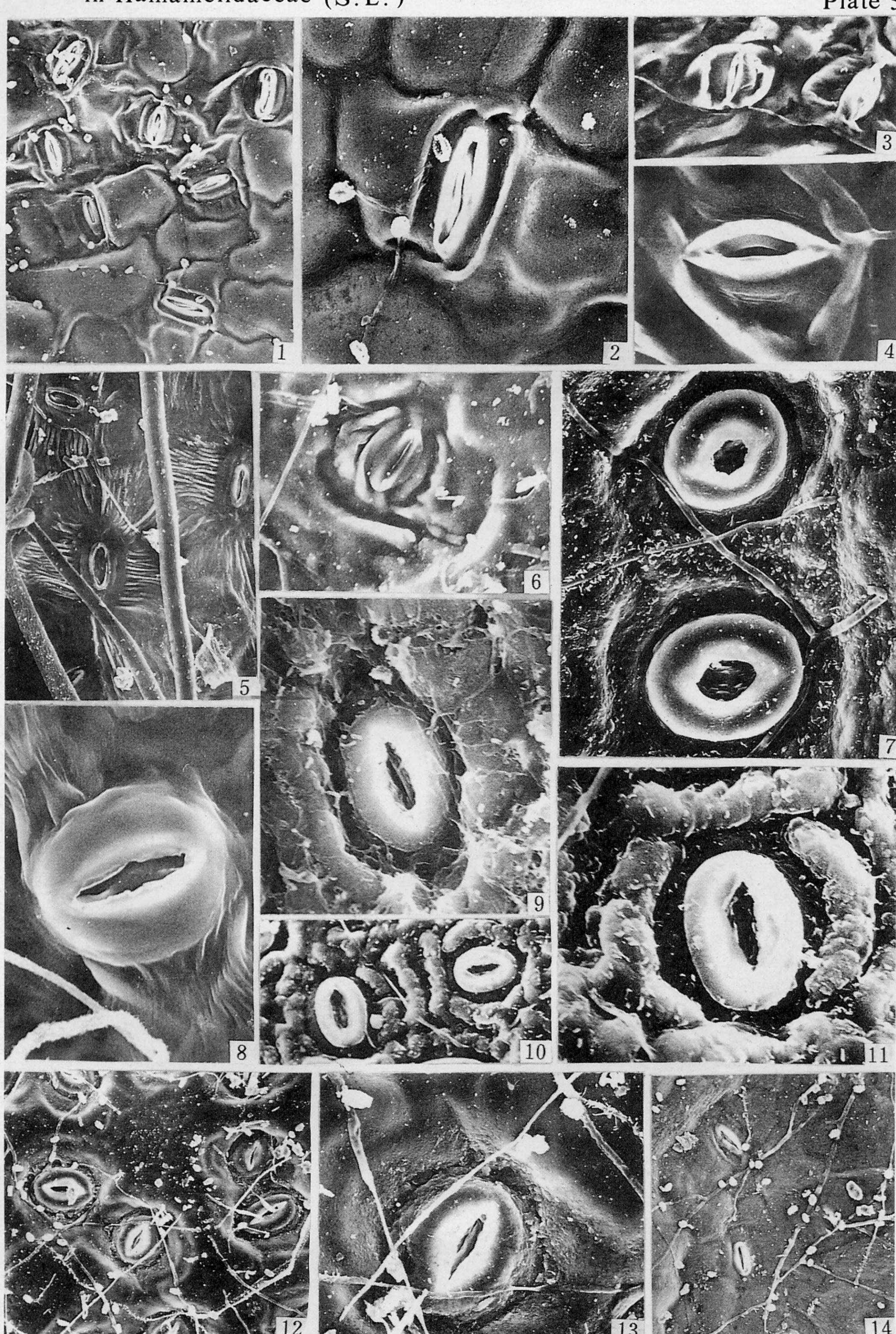
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